Search for Exotic Baryons with a K^+ Beam

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Rare Kaon Decay Workshop

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My Assumptions

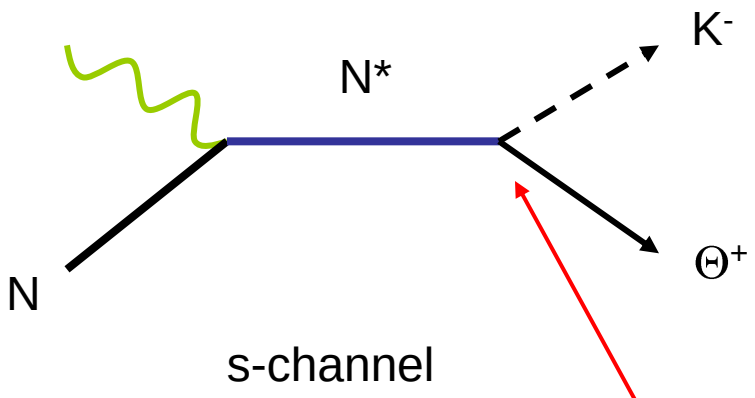
- Everyone here knows about pentaquarks.
- The pentaquark is not yet “dead”.
  - Let’s look at the evidence.
- The new LEPS data
  - Published in 2009, it supports the pentaquark.
  - Can it be reproduced at higher statistics?
- A K^+ beam experiment at Fermilab could settle the issue.

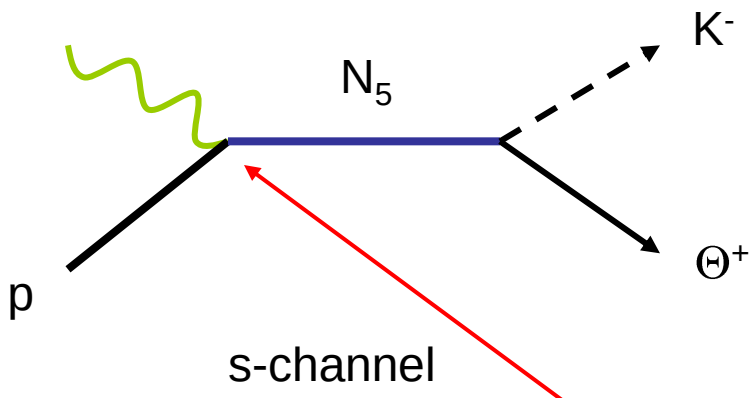
The 1st Five Measurements

Original Result **Repeat Measurement**

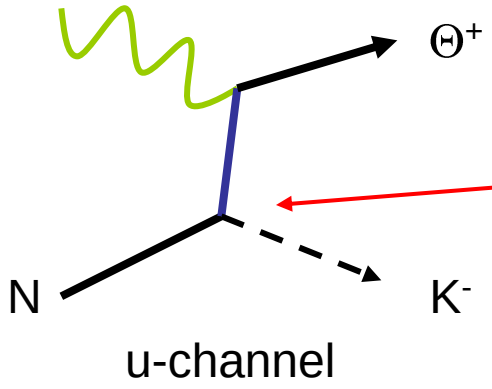
Collab	React	σ's	Collab	React	Incr	Result
LEPS	$\gamma C \to K^+K^-$	~4	LEPS	$\gamma d \to K^+K^-$	~5	~5σ
~~Diana~~	~~$K^+Xe \to \Theta$~~	~~~4~~	Belle	"K^+"Si	~10	Γ_Θ<1
~~CLAS~~	~~K^+K^-pn~~	~~5~~	CLAS	same	~30	σ<3 nb
~~Saphir~~	~~$\gamma p \to KK^+n$~~	~~5~~	CLAS	same	>10	σ<1 nb
~~hermes~~	~~ed $\to K^0p$~~	~~~4~~	Babar	$eA \to K^0p$	>100	???

Suppressed Kinematics





U-spin suppressed



Requires 2 $q\bar{q}$ pair production (OZI suppressed).

Forward-angle production is preferred.

Other Facts

- Many high-energy experiments with high statistics do not see the Θ^+.
- The KN scattering database: if the Θ^+ exists, it width $\Gamma < 1$ MeV.
  - No other strongly-decaying resonance has such a small width.
  - There could be strong suppression of the width due to its wave function.

Experimental Situation

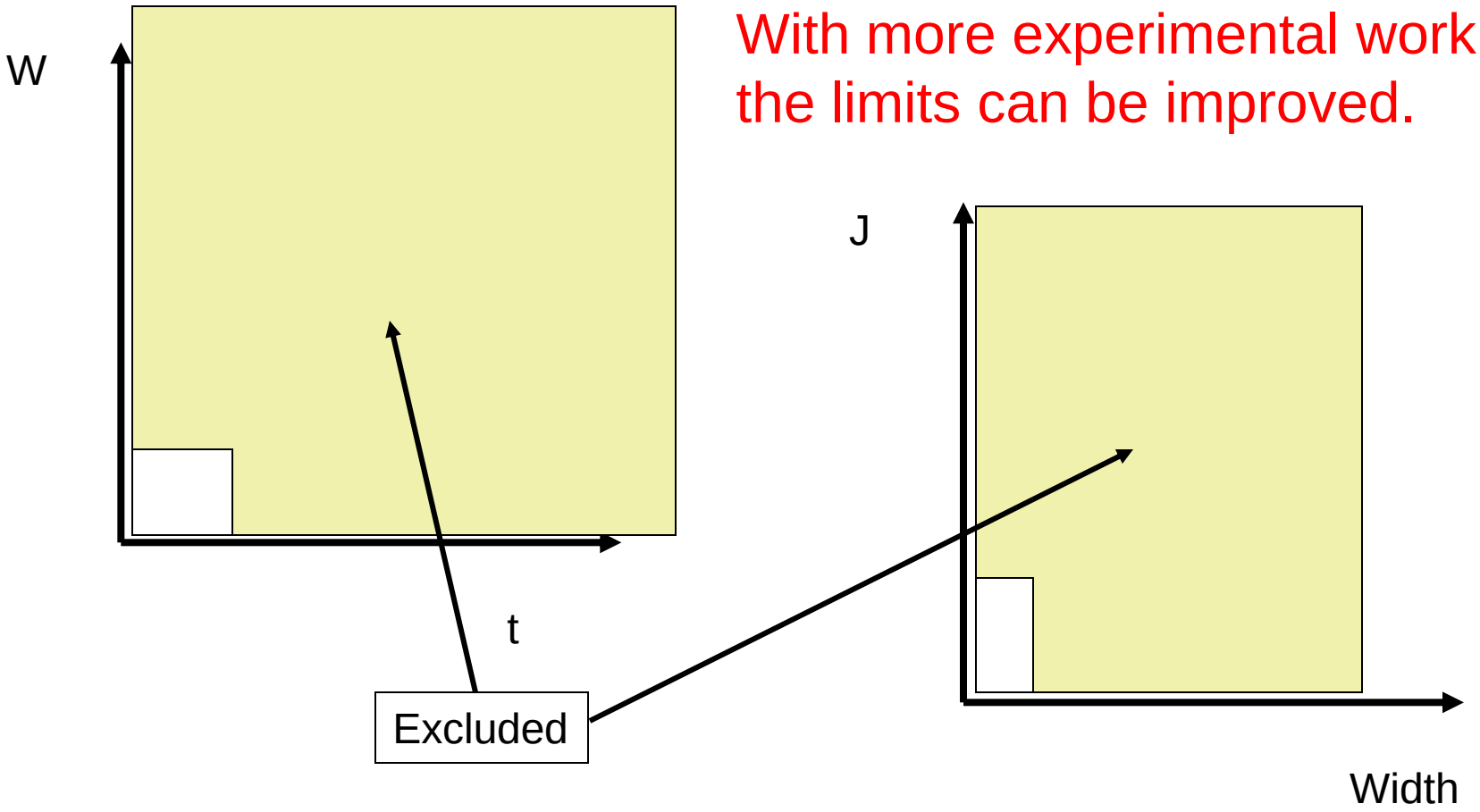
- There are many null results.
  - No Θ^+ from e^+e^- or high energy collisions.
  - 3 positive cases repeated, all null results.
- Only 2-3 results still appear viable:
  - LEPS $\gamma d \rightarrow K^+ K^- X$ (forward angle).
  - CLAS $\gamma p \rightarrow \pi^+ K^- K^+ n$ (π^+ goes forward).
  - DIANA bubble chamber data (reproduced?)

Lattice Calculations

- Many lattice calculations were done for the spin-parity $\frac{1}{2}^+$ and $\frac{1}{2}^-$.
  - Virtually all agree: no pentaquark signal.
- Two lattice calculations done for J=3/2.
  - Best is Lasscock et al., hep-lat/0504015.
  - Lattice signature: binding increases for lower pion mass—seen for all known baryons.
  - Study was redone with higher lattice statistics.

Exclusion Regions for Θ+

The Θ^+ is “painted into a corner”.
With more experimental work,
the limits can be improved.

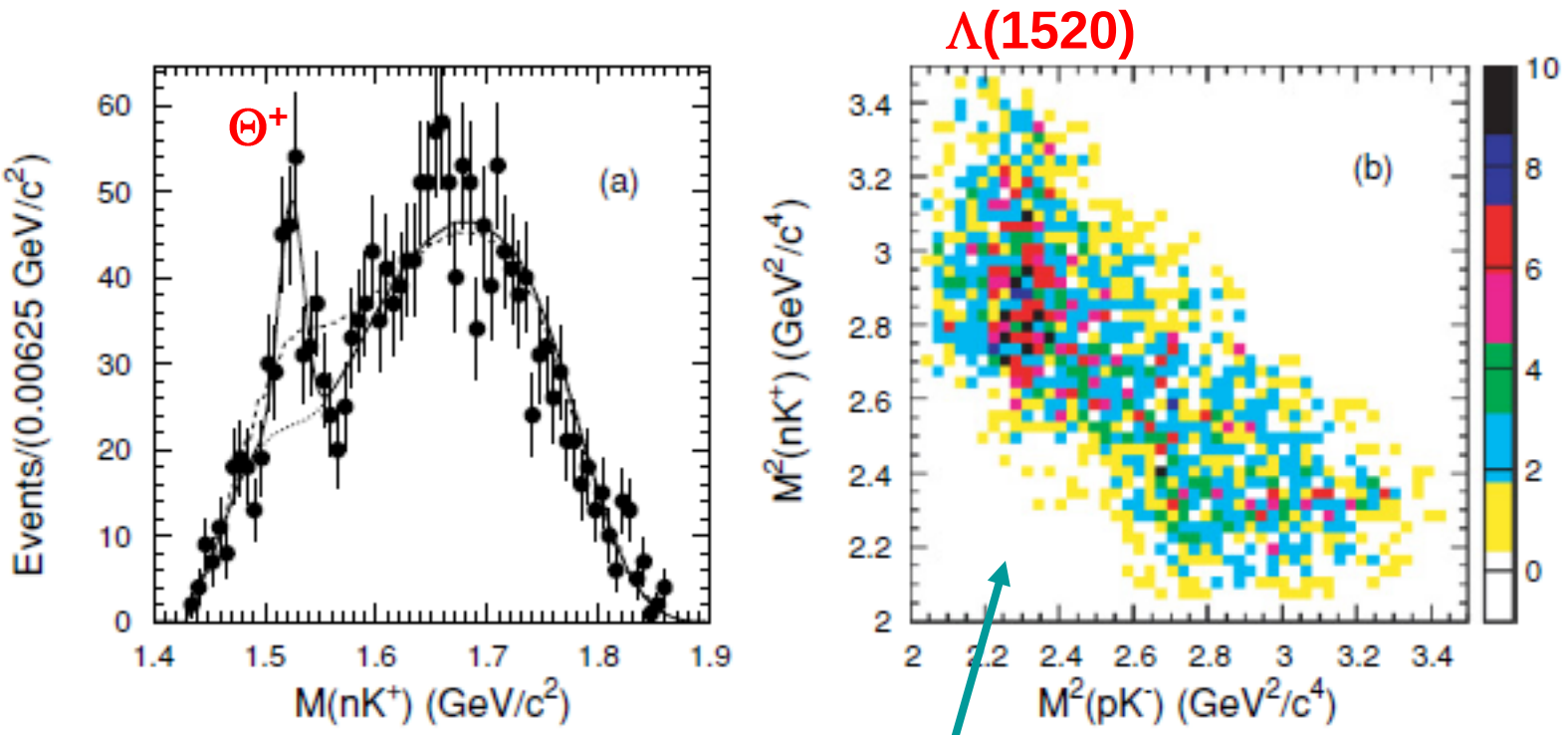


The LEPS deuterium data

- Deuterium data taken in 2002-3.
  - First publication was from a carbon target
- Deuterium data: factor of 8 higher statistics than carbon result.
- Background is better understood.

The Result

T. Nakano et al. (LEPS Collaboration), Phys. Rev. C 79, 025210 (2009).



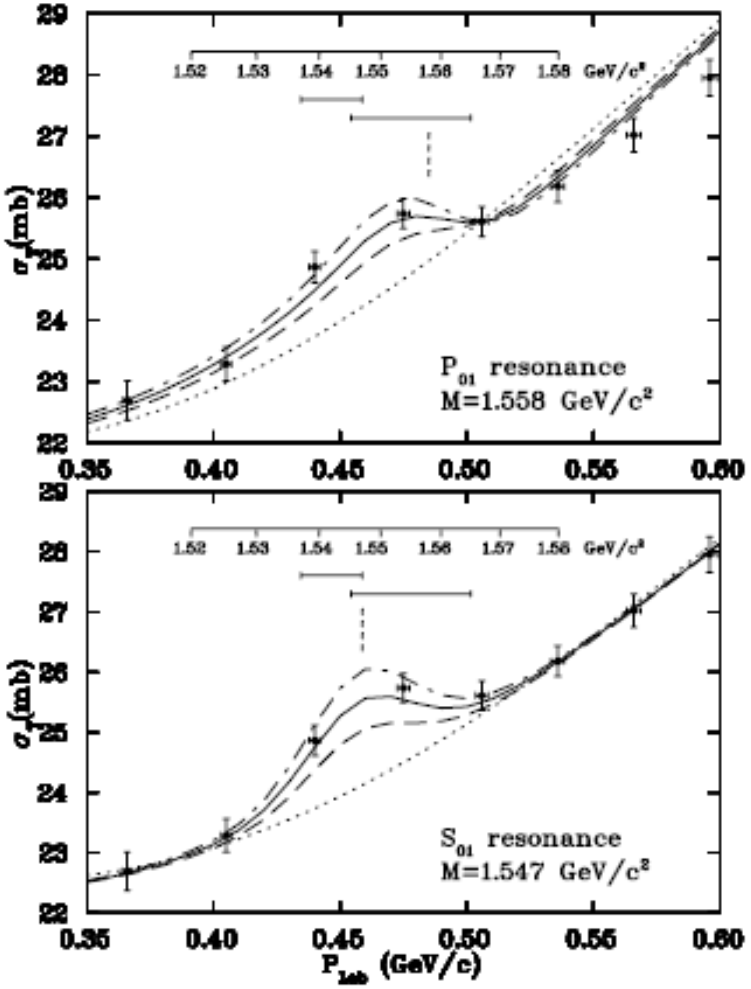
LEPS acceptance prevents overlap between resonances

The Next Step

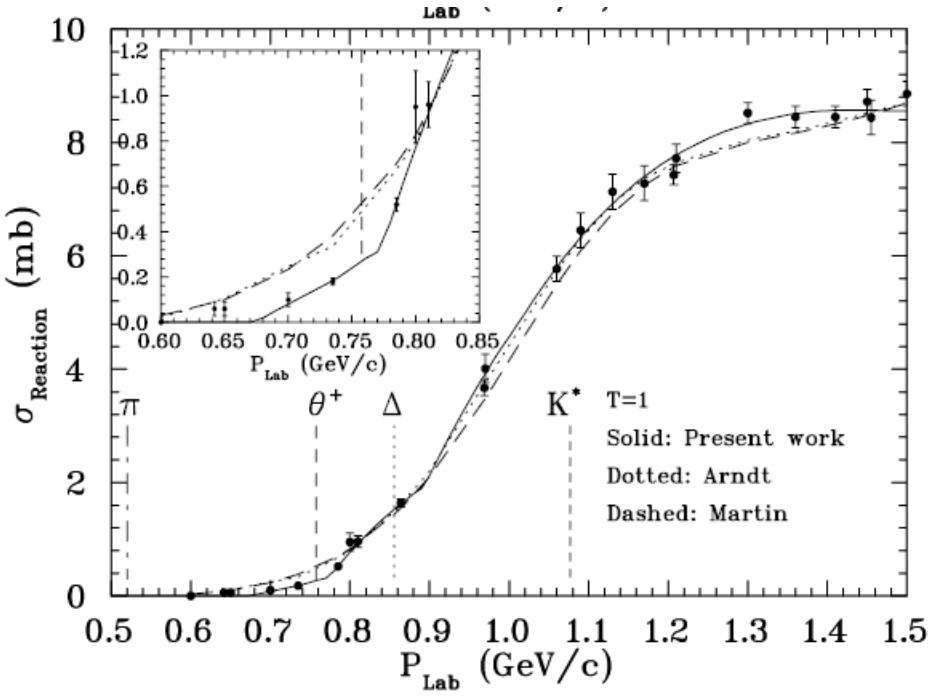
- There is another LEPS deuterium data set with twice the statistics.
  - We plan to do a “blind” analysis: same cuts.
  - Repeatability is the key to whether it’s real.
  - New analysis techniques were developed for this analysis: MMSA and RMM methods.
- If the Θ^+ is real, then it needs to be confirmed by some other experiment.

PWA of K^+N data by Gibbs

arXiv: nucl-th/0405024



arXiv: nucl-th/0611095

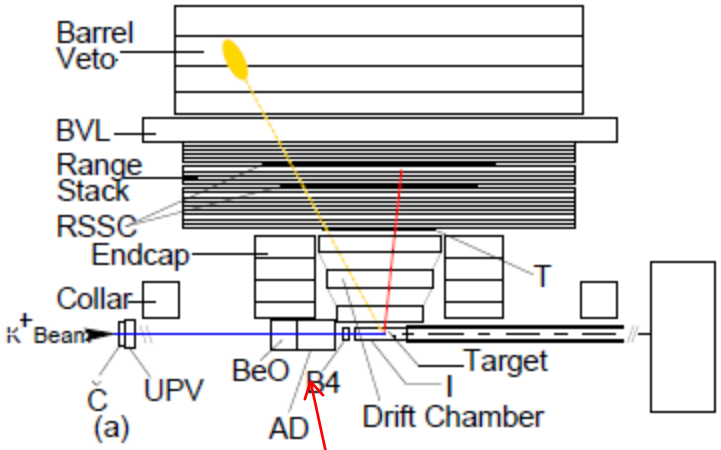


Includes a pion in the final state!

Conclusions from Gibbs (2006)

“The presence of a narrow pentaquark state would facilitate the understanding of pion production in the T=1 channel. In fact, the best way to look for a narrow resonance may be to produce it and look for a sudden change in the inelastic cross section. This was the way in which the existence of the J/psi was first indicated.”

E494 Detector as Example



Add Liquid Deuterium target here

Summary

- Theory suggests that it is still possible that a Θ^+ pentaquark exists with $J^P=3/2^+$.
- Experiments suggest that only a small kinematic window is available to the Θ^+.
  - The LEPS experiment is in this window.
- A measurement of the K^+d total cross section at Fermilab would be conclusive.
  - A real resonance MUST be seen there.